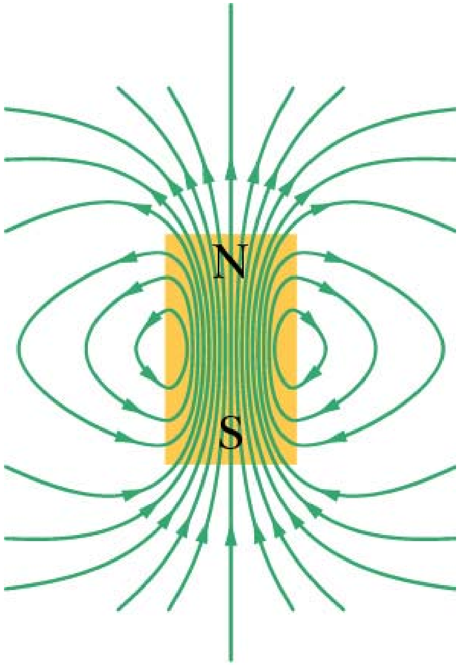
Magnetic Fields

- Analogous to electric field, a magnet produces a magnetic field, *B*

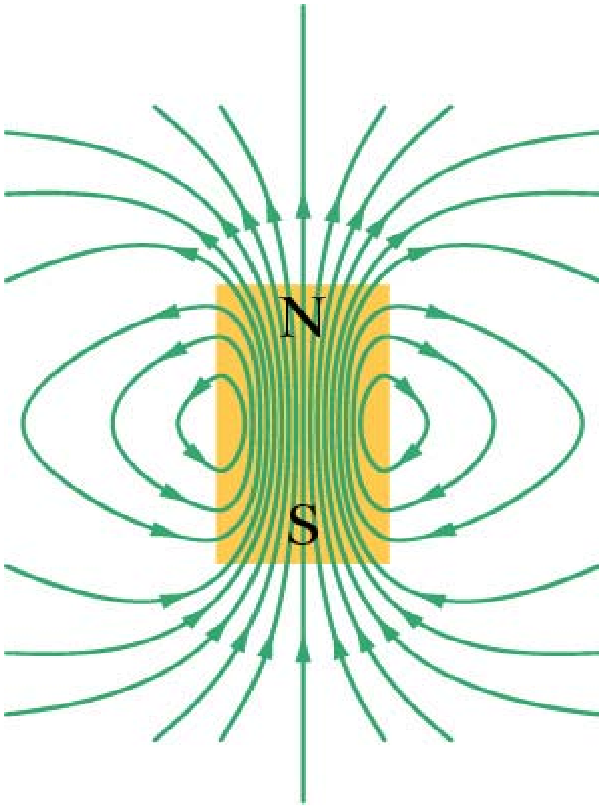
- Set up a *B* field two ways:
- Moving electrically charged particles
  - Current in a wire
- Intrinsic magnetic field
  - Basic characteristic of elementary particles such as an electron



(*a*)

Magnetic Fields

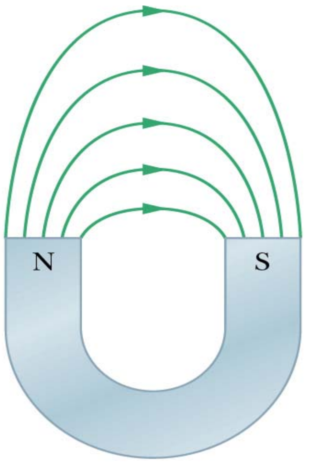
- Magnetic field lines
- Direction of tangent to field line gives direction of B at that point
- Denser the lines the stronger the B field



(a)

Magnetic Fields

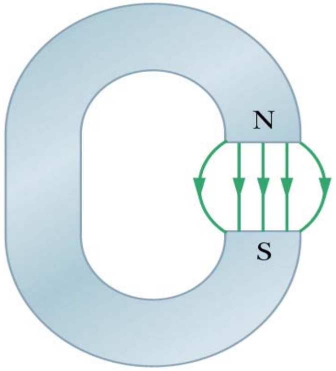
- Magnetic field lines enter one end (south) of magnet and exit the other end (north)



(a)

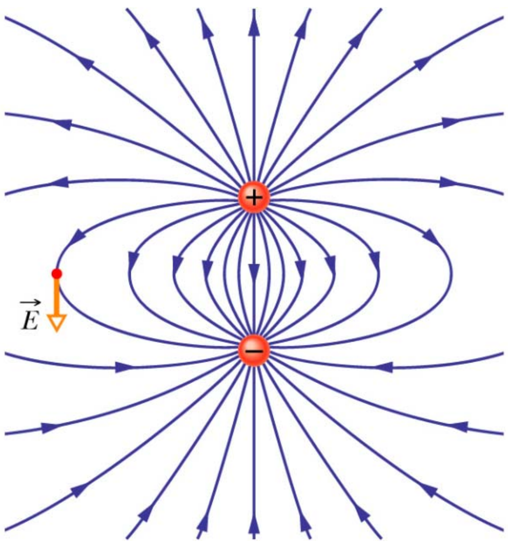
- Opposite magnetic poles attract

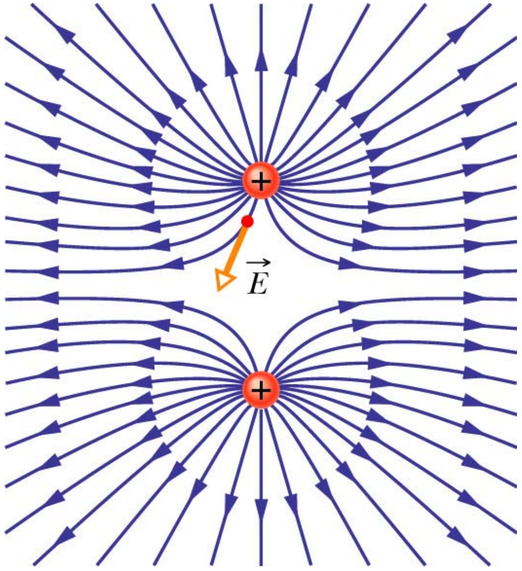
- like magnetic poles repel



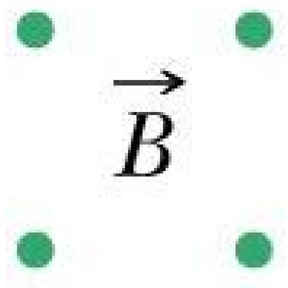
(b)

Like the electric field lines, but there are no "magnetic charges"

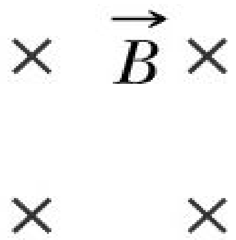




Magnetic fields



This shows the tips of magnetic field vector lines (green) pointed out of the screen (towards you).

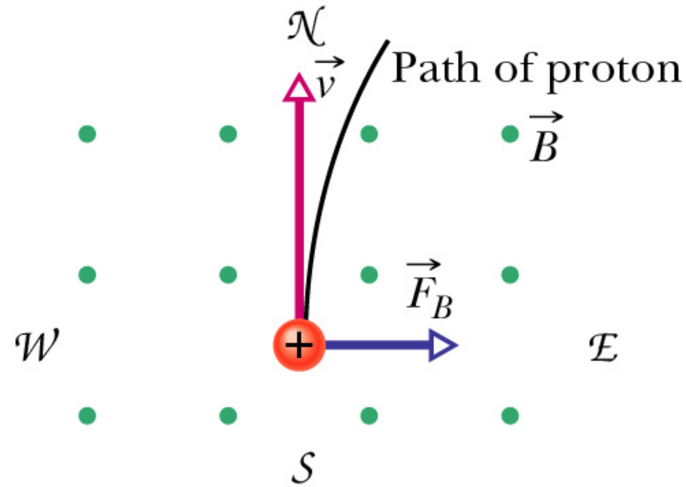


This shows the tails of magnetic field vector lines (black) pointed into the screen (away from you).

Lorentz Force

- When charged particle moves through B field, a force acts on the particle

$$\vec{F}_B = q\vec{v} \times \vec{B}$$



- Magnitude of F_B is

$$F_B = |q| vB \sin\phi$$

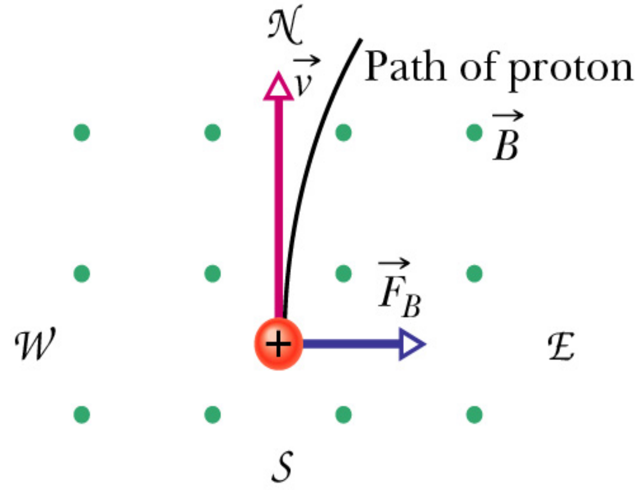
- where ϕ is the angle between v and B

- SI unit for B is tesla, T

$$1T = 1\frac{N}{C \cdot m/s} = 1\frac{N}{A \cdot m}$$

Lorentz Force

$$\vec{F}_B = q\vec{v} \times \vec{B} = qvB\sin\phi$$

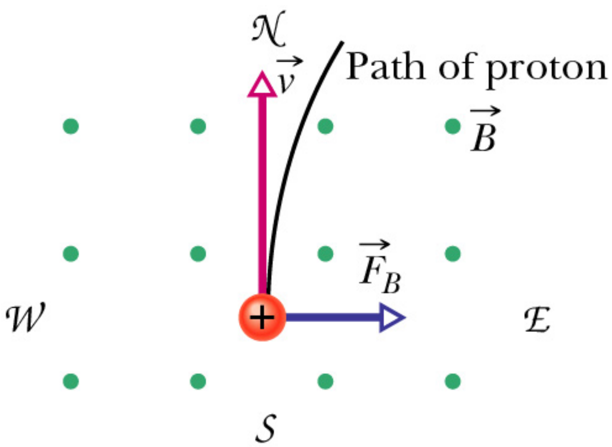


- F_B = 0 if
  - Charge, q = 0
  - Particle is stationary
  - v and B are parallel (ϕ=0) or anti-parallel (ϕ=180)

- F_B is maximum if
  - v and B are ⊥ to each other

Lorentz Force

$$\vec{F}_B = q\vec{v} \times \vec{B}$$

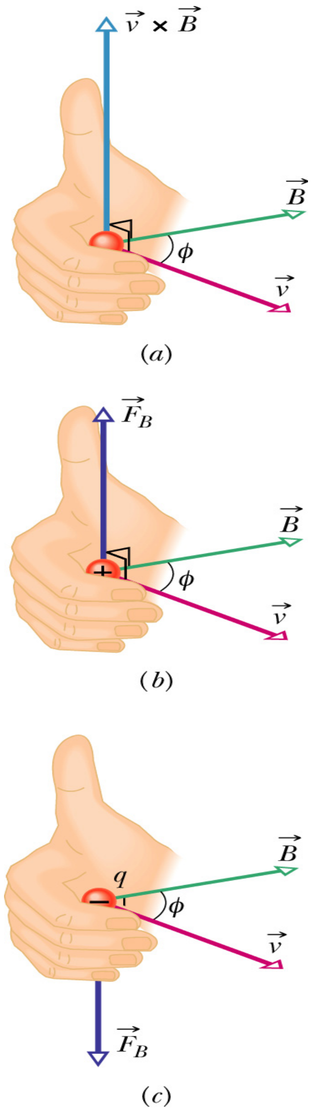


- F_B acting on charged particle is always ⊥ to v and B

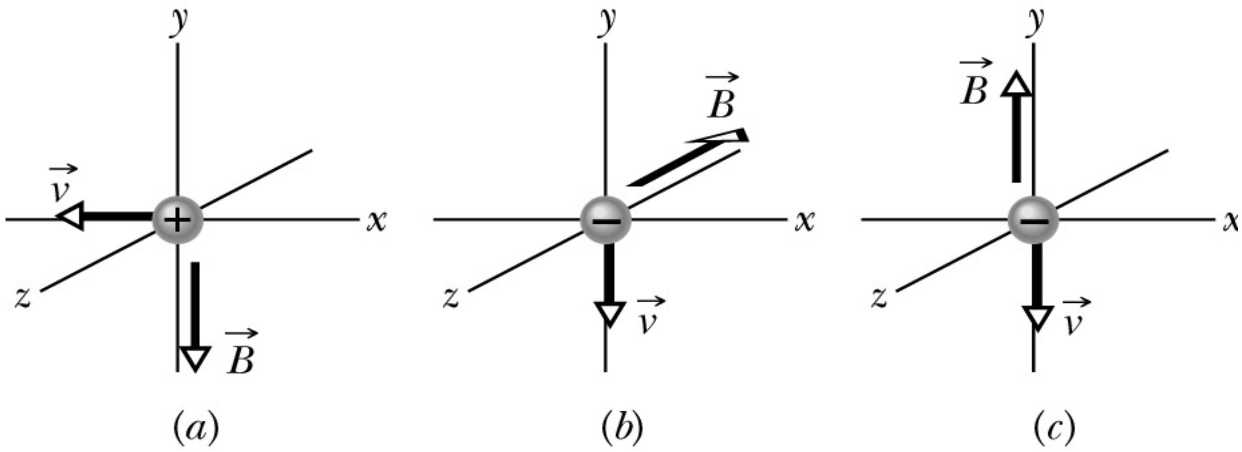
- F_B never has component || to v
- F_B cannot change v or K.E. of particle
- F_B can only change direction of v

Right-hand rule

- Right-hand rule – For positive charges - when the fingers sweep v into B through the smaller angle ϕ the thumb will be pointing in the direction of F_B
- For negative charges F_B points in opposite direction



Exercise



- What is the direction of F_B on the particle with the v and B shown?
- Use right-hand rule - don't forget charge

A) +z

B) -x

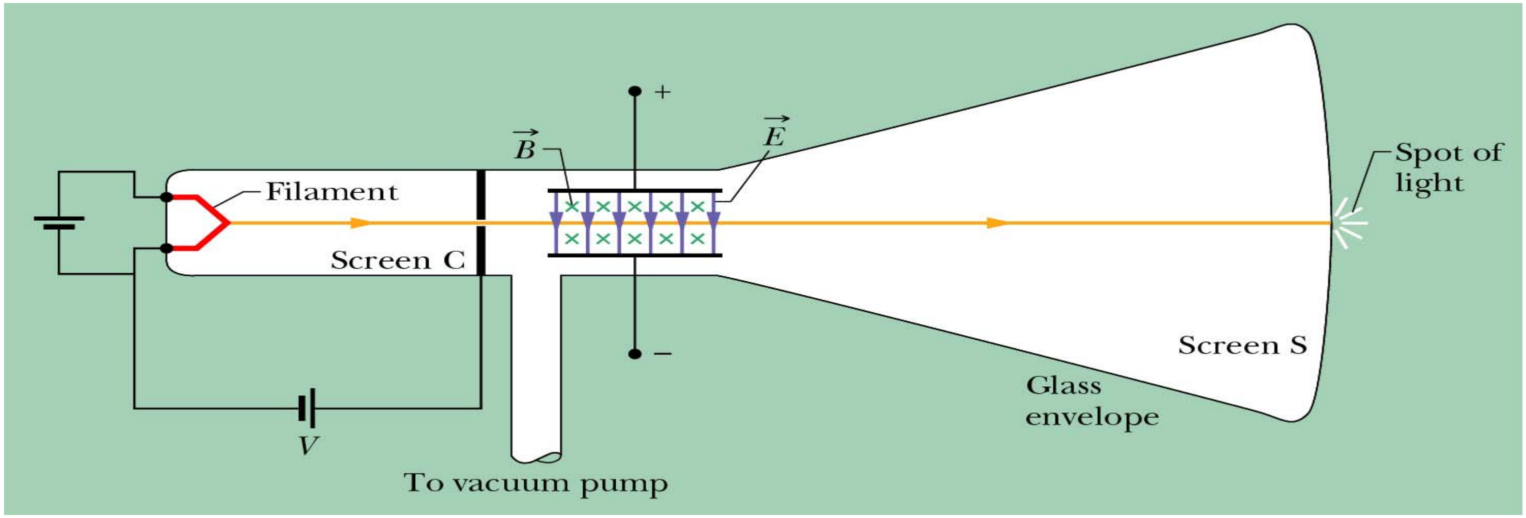
C) zero

$$\vec{F}_B = q\vec{v} \times \vec{B}$$

Magnetic Fields

- What happens if there is both an E field and a B field?
- Both fields produce a force on a charged particle
- If the two fields are $\perp$ to each other call them crossed fields

TV tube



- Cathode ray tube – used in television
- Can deflect a beam of electrons by
  - *E* field from charged parallel-plates
  - *B* field from magnet
- Adjust *E* and *B* fields to move electron beam across fluorescent screen

Exercise

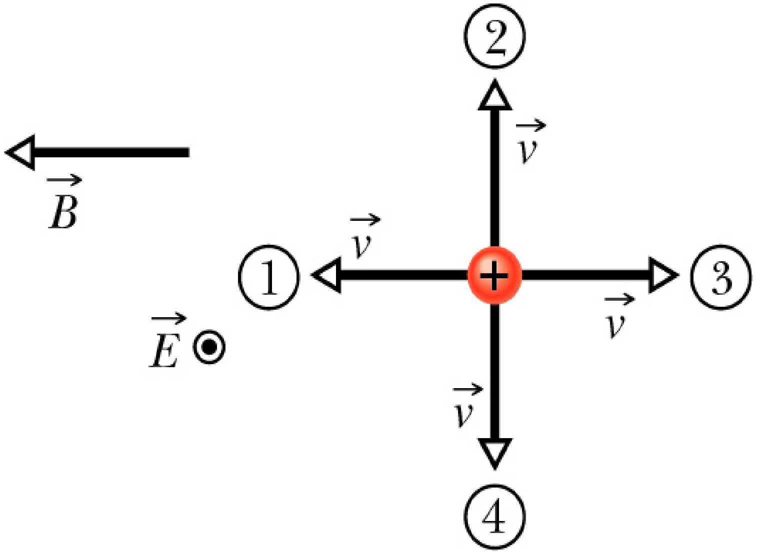
- E field out of page, B field to left
- A) Rank 1,2, and 3 by magnitude of net F on particle, greatest first

- What direction is F_E for 1?

Out of page

- Is it the same for all directions of v?

YES



Exercise

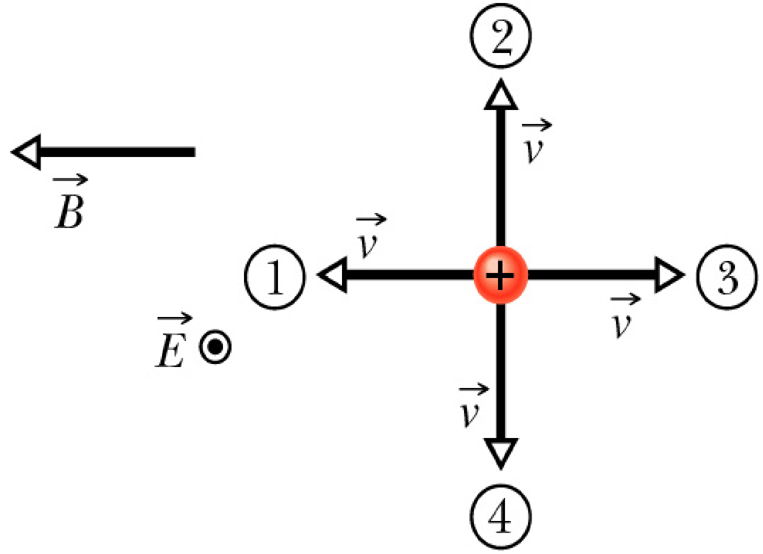
- What is direction of F_B for 1,2,3 and 4?

1) $F_B = 0$

2) F_B out of page

3) $F_B = 0$

4) F_B into page



- A) Rank magnitude of net F for 1, 2 and 3.

2, then 1 & 3 tie

- B) Which direction could have net F of zero?

Direction 4